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DOUGLAS-FIR CONE AND SEED INSECT BIOLOGICAL AND CONTROL STUDIES: PROGRESS IN 1958, 1959

by

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Foresters in the Pacific Northwest are giving increased attention to use of high quality Douglas-fir seed. Insect damage is one phase of seed investigations being conducted by our forestry research staff at Centralia. The objective is to develop a sound basis for control of the important cone and seed insects of Douglas-fir. The reporting of progress from these studies should prove of timely interest. The present paper on cone and seed insects of Douglas-fir in western Washington and Oregon contains sections on: (1) a key to seed-damaging larvae common in green Douglas-fir cones in western Washington, (2) the period of emergence and attack of the adults of these same larvae, (3) chemical control tests and (4) precautions on the use of insecticides. Changes in both the scientific and common names of the insects dealt with in this paper has resulted in some confusion. The following list of "Names used" with the "Explanatory notes" is included to give the various synonyms with references where the name was originally used.

1/ The authors, Forest Entomologist and Technologist, respectively, express appreciation for fine cooperation that facilitated these studies: Chemical companies for supplying insecticides to test; members of our forestry research staff, Dr. J. H. Rediske, Dr. W. H. Lawrence, and Michael J. Wotton on insecticide studies, W. H. Cummings for guidance on design; forestry personnel of Weyerhaeuser Company on carrying out studies on St. Helens, Vail-McDonald, and Clemons Tree Farms; and Mr. A. F. Hedlin of the Canadian Department of Agriculture for suggestions on the manuscript.

Names usedExplanatory notes

Douglas-fir cone moth

Barbara colfaxiana

B. colfaxiana vars. fir cone moth, Keen 1952; B. colfaxiana Kearf. Douglas-fir cone moth, Keen 1958; B. colfaxiana taxifoliella (Busch) Douglas-fir cone borer, Doane, et al. 1936; B. colfaxiana colorodensis (Heinrich), B. colfaxiana siskiyouana (Kearf.), and B. ulteriorana (Heinrich).

Fir cone worm

Dioryctria abietivorella

Formerly D. abietella (D & S) cone pyralid, Keen 1952, is superseded for our nearctic species by D. abietivorella (Grote) as contended by Munroe 1959; D. abietella is limited to palearctic--reported from Germany by Gaebler 1954.

Cone phalonid

Henricus fuscodorsana

Sitka spruce commophila, Doane et al, 1936; Spruce cone phalonid, Keen.

Douglas-fir seed chalcid

Megastigmus spermotrophus

Keen 1952, 1958; related M. spermotrophus var nigrodorsatus occurs on Pseudotsuga macrocarpa, Milleron 1946.

Douglas-fir cone midge

Contarinia oregonensis

Reports of gall-forming midge by Johnson, 1956, later identified as C. oregonensis Foote, Johnson and Heikkenen 1958, Hedlin 1959, 1959a.

Douglas-fir scale midge

Contarinia n. sp.

This second midge is a new species in course of description, Johnson and Heikkenen 1958; follow-up observations in British Columbia methods of distinguishing from C. oregonensis are given by Hedlin 1959.

REVIEW OF LITERATURE

On the biology of insects infesting the cones and seeds of Douglas-fir Keen's (1952) and (1958) reports are the most complete. Keen (1958) lists 63 species of insects reared from the cones of Douglas-fir, over half of which are considered parasites, 13 with unknown habits, and 17 which have been recorded as doing some damage. In addition to the insects reported on in this paper, Keen, (1958) considers of economic importance two species of Eupithecia (Geometridae). One of these is found in our area, but was not numerous during the period of this study. Keen also lists as "occasionally damaging" seed, moth species of Holcocera and Laspeyresia, and flies of the genus Earomyia: insects of the last two genera have been recorded in our area in limited numbers. Hedlin (1959) reports larvae of the spruce budworm occasionally feeding on and damaging Douglas-fir cones. Only the six species listed as important during the course of this study will be considered further in this paper.

The biology of the Douglas-fir cone moth has been detailed by Keen (1958) from work conducted in southern Oregon. Radcliffe (1952) and Hedlin (1959) have reported on the biology of this moth in British Columbia.

The fir cone worm does not confine its attacks to cones, but has been found mining in the shoots and bark of many different conifers (Lyons 1952). Habits of this species have been described by Lyons (1952), Craighead (1950) and Keen (1958).

The Douglas-fir seed chalcid has been the subject of many reports because of its introduction into other countries where Douglas-fir is grown. Keen (1958) reports that in addition to the Douglas-fir region of western United States, this chalcid occurs in New Zealand, Great Britain, Germany, and other parts of western Europe. This species has been reported to damage up to 50 percent of the seed of Douglas-fir near Ashland, Oregon (Keen, 1958); and damage has reached 100 percent in Great Britain (Hussey, 1955).

Miller (1916) has recorded in detail the process of oviposition of the Douglas-fir seed chalcid. Hussey (1955) has reported the most complete study of the biology of this species of chalcid. MacDougal (1906), Keen (1958), and Hedlin (1959) have made significant contributions also.

Many of the midges of the family Itonididae infesting Douglas-fir cones were described by Foote (1956) from material collected by Keen. However nothing was reported on the larval habits of these species until recently. According to Hedlin (1958) unpublished reports by Graham and Prebble attributed damage to midges as early as 1941. Damage by a gall-forming midge, Johnson (1956), was later identified as Contarinia oregonensis Foote on which the habits of larvae and adults are outlined and life stages and damage described, Johnson and Heikkinen (1958). Herein also they reported damage by another midge that is being described as Contarinia new species. Hedlin (1959, 1959a) has made further contributions to knowledge of these species.

Keen (1952) suggested chemical control of cone and seed insects with DDT. Since then, several reports have appeared on successful control of these insects attacking conifers. Rudinsky (1955) showed that a 2.5 percent water emulsion of DDT reduced damage to Douglas-fir cones from cone moths, chalcids and midges. He applied from 1 to 4 sprays from May until July and found increased protection with each treatment. Clark^{2/} using 2 pounds of 50 percent wettable powder DDT in 100 gallons of water applied at the rate of 5 gallons per tree, was able to reduce cone moth infestation from 80 to less than 10 percent. Fowells and Schubert (1956) reported that helicopter application of 2 pounds of DDT in 2 gallons of diesel oil per acre reduced the first year abortion of sugar pine cones caused by cone beetles (*Conophthorus*) from 56 to 14 percent, and second year damage from 77 to 8 percent. Allen and Coyne (1956) found that a 0.25 percent wettable and 0.5 percent emulsifiable benzene hexachloride (BHC) sprayed on first-year cones of slash and longleaf pine reduced insect damage. Cole (1958) reported that helicopter application of 12 ounces of 36 percent gamma isomer of BHC or its equivalent per gallon of oil reduced the loss of 31 percent of the cones of slash pine to 7 percent.

KEY TO SEED-DAMAGING LARVAE COMMON IN GREEN

DOUGLAS-FIR CONES IN WESTERN WASHINGTON

This key based on morphological and damage characteristics was designed for field use with aid of a 10 X hand lens. Material examined in preparing this key was taken from cones collected in western Washington during the period 1957-59. Larvae of each species were reared to adults; and specimens of both larvae and adults were sent to the U. S. National Museum for identification. Larvae of the Douglas-fir cone moth were removed from infested cones and placed in insect-free cones where they completed development. To accomplish this a small hole was bored into the cone with a cork borer, the larva inserted into the hole, the plug replaced in the hole, and the entire cone dipped in wax. The fir cone worms, cone phalonids, and both species of midge were reared by placing larval specimens on moist cotton in ice cream containers in a moist sand table. Seed chalcids were reared directly from infested seed.

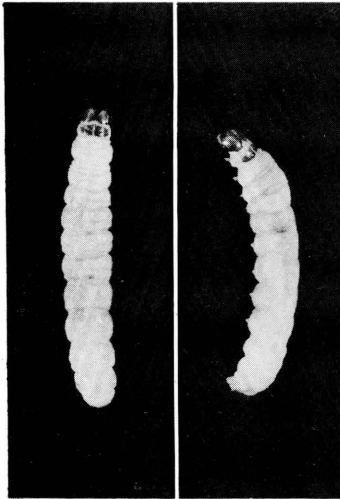
In using the following key it should be remembered that it covers only six species and that many other insect species inhabit Douglas-fir cones: Some damage the green cone, some are insect parasites and predators, and still others merely use the dry cone as a shelter.

^{2/} Courtesy of Dr. E. C. Clark correspondence dated February 1958, Moscow, Idaho, to Norman E. Johnson.

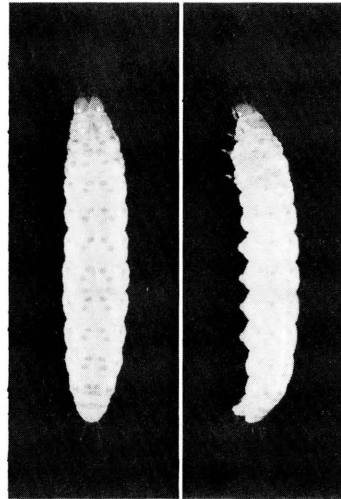
- 1a. Larva with legs, typical caterpillar; bores through cones leaving large amounts of frass (Plate I) 2
- 1b. Larva legless, maggot-like; confined to seed or single scale (Plate II) 4
- 2a. Larva with body hairs less than half as long as underlying segments; white or yellowish without conspicuous spots; $\frac{1}{2}$ inch long (Plate I A). DOUGLAS-FIR CONE MOTH
(Barbara colfaxiana)
- 2b. Larva with conspicuous hairs more than half as long as underlying segments; red or greenish with conspicuous spots. 3
- 3a. Larva with large spots; anal comb present; green; $\frac{3}{8}$ to $\frac{5}{8}$ inch long (Plate I A). CONE PHALONID
(Henricus fuscodorsana)
- 3b. Larva with small spots; and comb absent; red or purple sometimes with greenish tinge $\frac{3}{4}$ to $\frac{7}{8}$ inch long (Plate I A). FIR CONE WORM
(Dioryctria abietivorella)
- 4a. Larva entirely within seed; white; sclerotized biting mouth parts visible externally $\frac{3}{16}$ inch long (Plate II D)
DOUGLAS-FIR SEED CHALCID
(Megastigmus spermotrophus)
- 4b. Larva not found directly in seed; pink or orange; mouth parts inconspicuous even under high magnification. 5
- 5a. Larva pink, sometimes almost white; lives in woody galls; breast plate deep-notched and nearly as long as second body segment; $\frac{1}{8}$ inch long. (Plate II A, B)
DOUGLAS-FIR CONE MIDGE
(Contarinia oregonensis)
- 5b. Larva orange; mines in cone scale; breast plate shallow-notched and shorter than second body segment; $\frac{1}{8}$ inch long. (Plate II C) DOUGLAS-FIR SCALE MIDGE
(Contarinia n. sp.)

Plate I
LARVAE OF DOUGLAS FIR CONE AND SEED INSECTS
AND INFESTED CONES

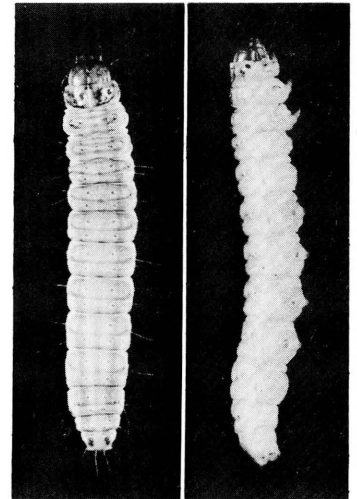
A. Larvae that infest Douglas fir cones.



DOUGLAS FIR CONE MOTH
Barbara colfaxiana
(2½x)

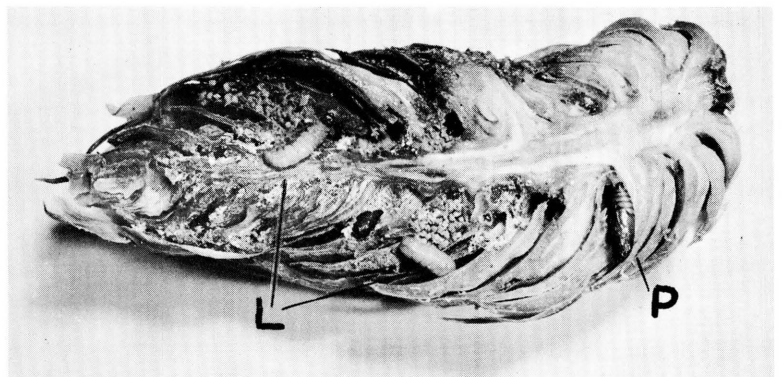


CONE PHALONID
Henricus fuscodorsana
(2½x)



FIR CONE WORM
Dioryctria abietivorella
(2½x)

B. Cone sectioned to show Douglas fir cone moth damage, with both larva, "L", and pupa, "P", present.



C. Cones damaged by fir cone worm. Note accumulation of frass and deformity of Douglas fir cones. Damage by the cone phalonid is similar.

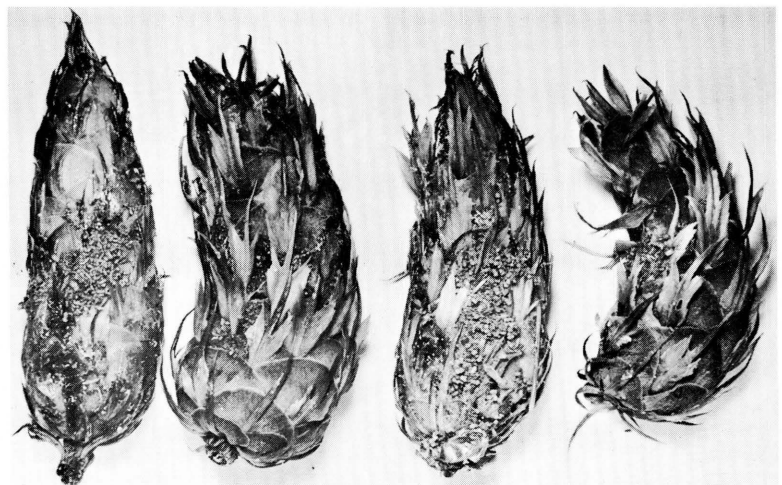
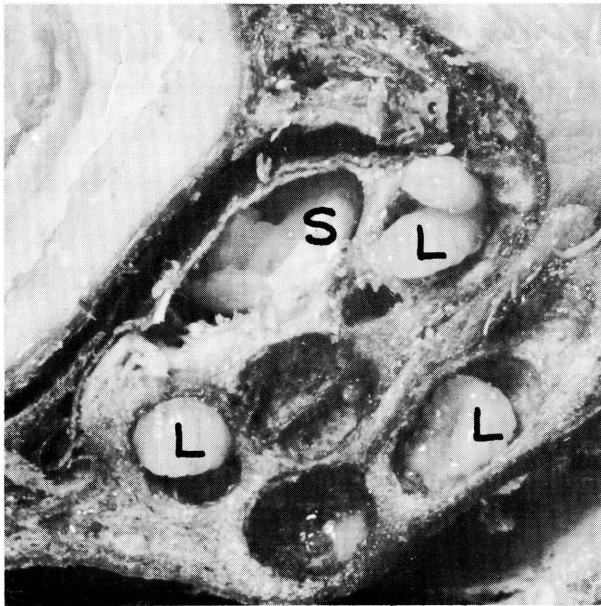
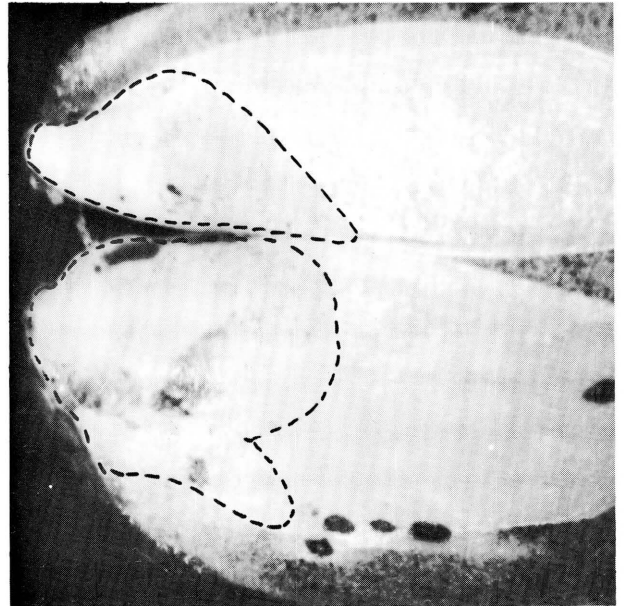


Plate II

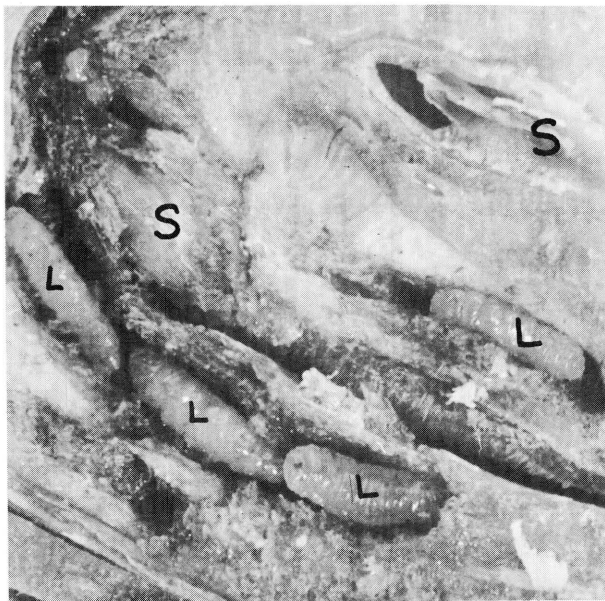
DOUGLAS FIR CONE DISSECTION TO SHOW
INFESTATION BY CONE AND SEED INSECTS.
"L", LARVA: "S" SEED.



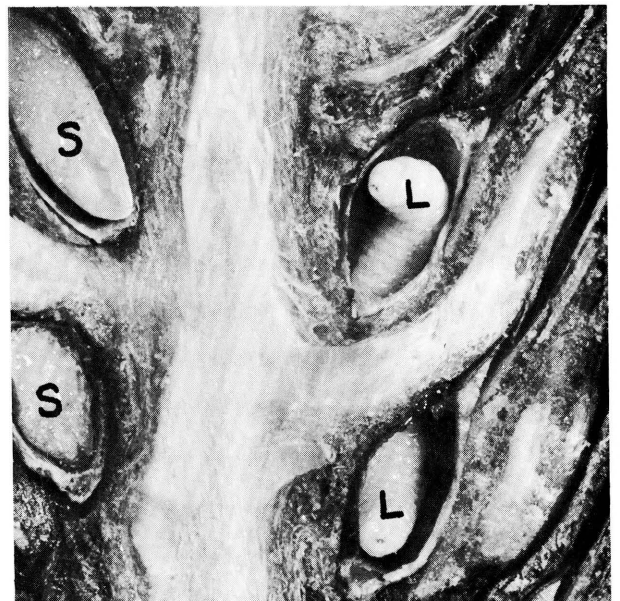
A. Gall damage to cone scale by Douglas fir cone midge. Note larvae coiled in gall pockets. (10x)



B. Cone scale with normal seed (above); and galled seed (below) 3 weeks after larvae hatched from eggs laid by Douglas fir cone midge. (5x)



C. Cone scale infested by Douglas fir scale midge. Note how larvae lie straight, and lack of galls -- both distinguishing from cone midge. (8x)



D. Seed infested with the Douglas fir seed chalcid, and uninfested normal seed. (7x)

PERIOD OF EMERGENCE AND ATTACK

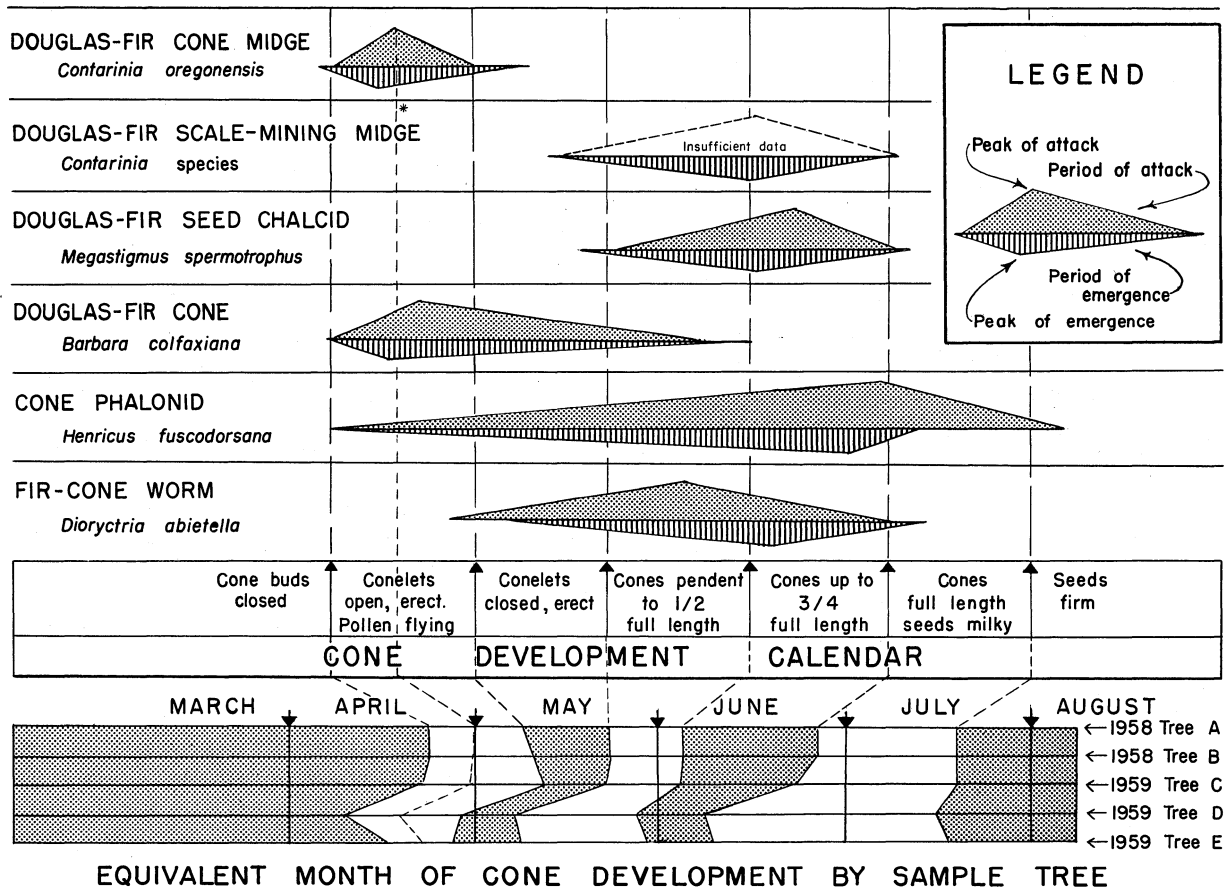
To provide a sound basis for control measures it was necessary to determine the period of emergence and attack of the major Douglas-fir cone and seed insects in our area. Little was known about the habits of the midges especially.

Methods

To determine the period of emergence of the various insects, rearing boxes made of exterior grade plywood, as illustrated in Plate IV, were placed on the forest floor and in the insectary at Centralia. After covering the bottom of the box with soil and forest litter to provide suitable conditions for pupation, Douglas-fir cones were collected and placed in the box. The boxes were visited at weekly intervals in the spring to collect emerging adults. At each visit phenological observations were taken on the stage of development of Douglas-fir cones. These included the following stages: cone buds closed; cone buds open, erect; cone buds closed, erect; conelets pendent, one-half full length; cones up to three-fourths full length; cones full length, seeds milky; seeds firm. Emergence period is correlated with the above phenological observations in Plate III. To determine the period of attack, cone-bearing branch tips distributed throughout the crowns of two trees were enclosed in bags in early April before the conelets had opened and before any insects were noted in the emergence traps. The bags, made of 32-mesh plastic screen (Lumite) were tied to the branch wrapped with a strip of cotton to make the enclosed branch tip insect proof (Plate IV). In the spring of 1958, at the earliest sign of cone bud opening, four bagged branches chosen at random were uncovered. Four new branches exposed to this date were covered for the remainder of the season. The following week four additional randomly chosen branches were exposed and the bags from these placed over those cones exposed the previous week. This sequence was used at weekly intervals at Clemons Tree Farm and bi-weekly intervals on the Yacolt area of St. Helens Tree Farm. Records were taken of the attack period of the various species of insects and of phenological observations from the time of cone bud bursting until summer when the cones were nearly mature. At this time all cones on numbered branches were collected and brought into the laboratory. Five cones were selected at random from each date of exposure. Each cone was dissected by boring with a cork borer along the axis starting at the base and peeling each scale off for examination under the microscope. All insects encountered were collected and placed in alcohol-filled vials for further identification. Each specimen was compared with larvae whose adult stage had been determined during the insect-rearing and identification phase of the study. The data for both trees were pooled and the duration and peak of the attack period correlated with the phenological observations made during the study.

Plate III

**PATTERNS OF DOUGLAS FIR CONE AND SEED
INSECT INFESTATION IN WESTERN WASHINGTON**



A. Calendar of attack and emergence by stage of cone development and equivalent month of year. For example* the cone midge attack is at peak when conelets are open or erect—a stage that occurs at dates varying with year and tree. In 1958 trees A and B, last of April; and in 1959, Tree C last, D early, and E mid-April.

B. Abundance of eggs laid by Douglas fir cone midge in scales from base to tip of cone varies by samples from a higher peak in samples from Clemons Tree Farm to lower in those from Yacolt.

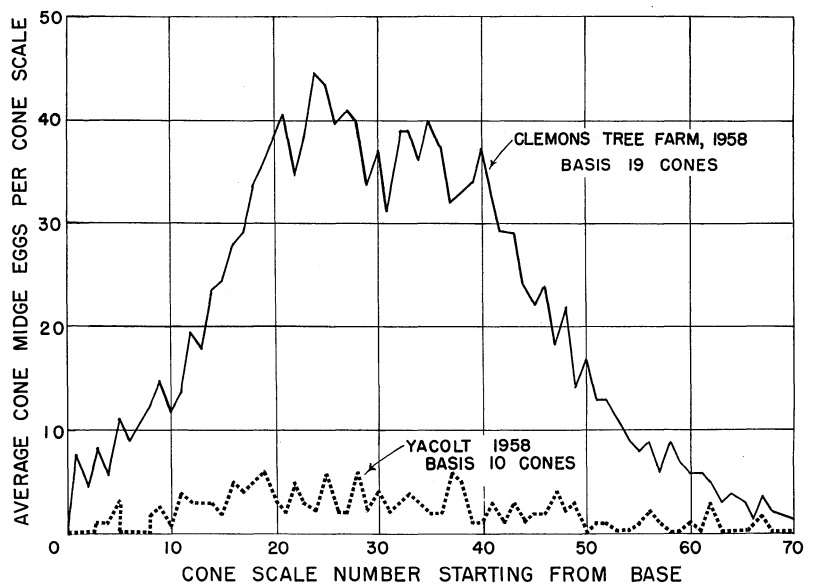


Plate IV

TECHNIQUES IN STUDIES ON CONTROL OF
CONE AND SEED INSECTS OF DOUGLAS FIR



A. Bagging of Douglas fir branch tip with 32-mesh lumite screen tied over cotton wrapping to prevent insect attack of cones.



B. Spraying cones on young Douglas fir trees with DDT to control insect damage in cone producing area at Yacolt.



C. Measuring insect emergence from Douglas fir cones in a cage with a layer of soil in the bottom.

D. Applying insect sprays by hand atomizer to individual conelets on tagged branches of Douglas fir from truck-mounted ladder.



In the spring of 1959 two additional trees were selected for similar study. These were located on the Gilbert Forest Proving Ground 12 miles southwest of Centralia. The crown of each tree was quartered both vertically into top, upper, lower, and basal portions, and horizontally into the four quadrants of the compass to give a total of 16 distinct crown segments. Within each segment a branch bearing at least five cone buds was selected and tagged. The treatments involved bagging of the branch tips on four dates at 3-week intervals: (a) the earliest, April 7, (b) the next, April 27, (c) third, May 17, and (d) last, June 7. The resultant 16 combinations were assigned to branch positions using crown height as rows, and quadrants as columns in a 4 x 4 quasi-Latin square pattern confounding less important interactions with rows and columns. Four cones were the basis for each determination, except where fewer cones were available. The treatments and number of midges recovered per cone are shown in the Appendix.

Results

The Douglas-fir cone moth emerges from a few days before the cone buds open until early June. The heaviest attack occurred during the period when the conelets were open to pollination, but continued until the cones were $3/4$ full length (Plate III). The female is active during early evening and lays eggs of flattened shape on the bracts when the conelet is open for pollination. This continues until the conelet has closed and turned down. The larva hatches from the egg after one or two weeks and at first feeds on the cone scales, later feeds around the axis of the cone on developing seed (Plate I). By the first of August most of the larvae have pupated in the cone. The pupae overwinter in cones and emerge in the spring as adult Douglas-fir cone moths. Keen (1958) and Radcliffe (1952) from study of the biology of this species report that some of the pupae remain in the cones up to three years before emerging as adults.

Attack by the fir cone worm extended from the first week in May until mid June. However, one larva was found in cones bagged since early April. Unless the bag was not insect proof the larva resulted from an egg laid the previous fall. This would confirm the report by Keen (1958) that some adults lay eggs in the spring but other oviposit in the fall. The large larvae feed in one or more cones during their development, producing large amounts of frass. Often they are found attacking at points of injuries made by the Douglas-fir cone moth. Usually the fir cone worm pupates in the soil rather than in the cone.

The cone phalonid was found common on the Clemons Tree Farm where it attacked cones exposed from the first of May until the middle of July. In this area only two specimens emerged from the rearing boxes on June 16, 1958. In the laboratory, emergence occurred from the last week in April until the first of July, which indicates a long period of attack. This insect leaves the cones to pupate.

The Douglas-fir cone midge has caused more damage to Douglas-fir seed than other insects the past few years in western Washington. This insect overwinters in the forest litter as a larva, transforming to the pupal stage in the spring, and, two to three weeks later to the adult small fly. Examinations were made of forest litter in which midge larvae had been released in large numbers. Results showed that over 80 percent of the larvae overwinter in the decomposing layer of litter with about 15 percent in the upper layer of raw humus and less than 5 percent in the underlying soil. As shown in Plate III emergence extends over a period of 3 weeks to a month. From rearing cages in the field, as much as 50 percent of the emergence was delayed until the second spring, indicating a diapause as found in other cone and seed insects. The female midges, after being fertilized, back in between the bracts with ovipositors extended and wings raised vertically. Eggs are then laid in groups principally between the seam of overlapping cone scales near the seed. The period of attack appears to be restricted to the time that the conelets are open (Plate III). After the conelets close the female is apparently unable to place the ovipositor into the preferred area of oviposition.

The study conducted during the spring of 1959 gave confirmation that cones are subject to attack by the Douglas-fir cone midge only when open. The two trees chosen for the study flowered 19 days apart. Although midges were present in the area over the entire period of flowering, the conelets were infested only when open. Thus, on tree no. 2 which flowered early, all the cones exposed during the period of April 7 to 27 were infested with midges. By contrast, on tree no. 1 whose cones had just begun to open on April 27, only one cone of 32 was infested. During the April 27 to May 7 period of exposure no cones were infested on tree no. 2 whose cones had all closed, and all were infested on tree no. 1. This points out clearly that the conelets must be open in order to be infested by the cone midge. The average number of Douglas-fir cone midges per Douglas-fir cone on sample trees during successive stages of exposure to attack from April 7-June 7, 1959 was as follows:

Sample Tree	Flowers open from--	Before flower- ing	Flower open	After flower- ing	Through- out	Control, never exposed
		<u>no.</u>	<u>no.</u>	<u>no.</u>	<u>no.</u>	<u>no.</u>
No. 1	Apr.27-May 11	0.2	35.8	0.0	14.3	0.0
No. 2	Apr.8-27	<u>0.0</u>	<u>15.7</u>	<u>0.0</u>	<u>8.0</u>	<u>0.0</u>
Both		0.2	51.5	0.0	22.3	0.0

Counts of the Douglas-fir cone midge eggs at Clemons Tree Farm in 1958 showed up to 1,500 laid per cone with definite patterns of frequency. Egg distribution in heavily infested cones concentrated in the mid portion with fewer eggs toward each end of the cone; whereas, in lightly infested cones this strong central tendency was lacking (Plate III).

Study	Buds closed <u>no.</u>	Buds half open <u>no.</u>	Buds completely open <u>no.</u>	Cone scales closed <u>no.</u>
Clemons	0	236	1544	1414
Yacolt	<u>0</u>	<u>15</u>	<u>80</u>	<u>157</u>
Average	0	126	812	786

The eggs hatch after about 2 weeks and the microscopic white larvae feed in the vicinity of the seed. After 2 to 4 weeks the tissue around the seed begins to swell, and a gall is formed that may fuse the seed to the cone scale (Plate II). The larva develops in its own compartment in a single or aggregate gall. In the late fall or early spring the larva leaves the cone to pupate in the forest litter.

In 1959 counts of midge larvae emerging from Douglas-fir cones maintained under different conditions of moisture in the insectary showed marked differences. The number of emerging larvae averaged greatest for the Douglas-fir cone midge from wet cones, and next greatest for the Douglas-fir scale midge from fresh cones, as shown in the following table.

Sample No. (of 25 cones ea.)	Douglas-fir cone midge larvae emerging per---			Douglas-fir scale midge larvae emerging per---		
	Fresh to	Dried	Wet	Fresh to	Dried	Wet
	dry cone	cone	cone	dry cone	cone	cone
	<u>no.</u>	<u>no.</u>	<u>no.</u>	<u>no.</u>	<u>no.</u>	<u>no.</u>
1	2.0	0.5	86.6	1.2	0.3	0.0
2	2.6	.2	42.1	12.0	4.0	.2
3	<u>1.7</u>	<u>.0</u>	<u>16.1</u>	<u>42.5</u>	<u>.0</u>	<u>1.0</u>
Average	2.1	.3	44.9	18.6	1.4	.4

Hedlin, (1959) found the Douglas-fir cone midge emerged in greatest numbers from wet cone scales at low temperature. This suggests probable peak emergence under natural conditions during fall rainy season.

The Douglas-fir scale midge is an undescribed species found attacking cones of Douglas-fir. It has been abundant the last two years in Washington and also in British Columbia (Hedlin 1959). The adults emerge from the soil where the larvae have overwintered in cocoons, and desposit their eggs under the bract of the pendant cone in early June-- the exact time is still to be determined. The larvae upon hatching from the egg bores into the cone scale where they feed. When present in great numbers, the cone scale may turn brown. Occasionally the seed is penetrated also. Douglas-fir scale midges were prevalent in cones bagged from April to July; here the bagging had not protected the cones. Thus attack was dated only from emergence dates which run from last week in May to third week in June. This is nearly a month later than emergence of the Douglas-fir cone midge.

The Douglas-fir seed chalcid emerged from the last of May to early June. Plate III shows the recorded period of attack-- when the cones are pendant, closed, and about $3/4$ their ultimate length. The female, which emerges a few days after the male, lays eggs within the seeds by inserting the long ovipositor through the cone scales. The larva develops entirely within the seed and may emerge as an adult the following spring, or one or two years later according to Hussey (1955).

CHEMICAL INSECTICIDE TESTS

On a cone producing and experimental area established in young second growth Douglas-fir on the old Yacolt burn on St. Helens Tree Farm, insects destroyed 84 percent of the seed crop in 1957. In order to reduce recurrent damage, seed-producing trees were treated with DDT in the spring of 1958. In 4 established blocks, the plots testing differential soil fertilizing treatments were treated with DDT at the time the conelets were erect and shortly after pollination. Two weeks later blocks I and IV were given a second treatment. Fertilized trees surrounding the plots were left as untreated controls. The first spray was timed to coincide with the period of maximum activity of the adult Douglas-fir cone midge and Douglas-fir cone moth. The second application approximated the period of maximum hatching of eggs of the Douglas-fir cone moth. Treatment was with 25-percent emulsifiable concentrate of DDT at the rate of 1 gallon of concentrate per 100 gallons of water. This insecticide was applied at 5 gallons per tree from a tank truck of 2000-gallon capacity which developed pressure sufficient to shoot a stream 40 feet into the air. On some of the trees 50 feet tall the insecticide did not reach the top-- which remained untreated (Plate IV). Both the single spraying with DDT, and the double application gave significant protection to the cones from the Douglas-fir cone moth; however, neither treatment controlled the Douglas-fir cone midge. This is evident in the seed damage percent:

DDT spraying	Seed damaged by --			Sound seed per cone cut	Cones tested, basis
	Douglas- fir cone moth	Douglas- fir cone midge	Both insects		
	<u>pct.</u>	<u>pct.</u>	<u>pct.</u>	<u>no.</u>	<u>no.</u>
Untreated: Check	30.5	9.6	40.1	1.2	110
Single: May 7	20.0	11.8	31.8	1.6	185
Double: May 7, 21	9.1	9.3	18.4	4.2	175

Although DDT has given some control in initial studies tests are extended to determine the effectiveness of other insecticides in reducing damage by cone and seed insects. Two studies were conducted: one to test promising insecticides, and the other to determine optimum time of spraying. Both studies employed a technique of spraying conelets on individual branches.

For the test of promising insecticides two trees, one at Camp McDonald and one at Yacolt, Washington, were selected. Using the truck-mounted ladder shown in Plate IV, 24 branches bearing 5 or more cone buds were selected. The branches were chosen so that one would not be contiguous or directly over another at the tip which bore the cones to be treated. The insecticides were made from technical grade chemicals with water and surfactant, Rexex-20, at one percent to give the prescribed concentration in a one-pint polyethylene measure. The concentrations, where applicable, were those recommended for codling moth control and double that amount (U. S. Dept. Agr. 1958; Wash. State Col., 1957). The insecticides were applied to randomly chosen branches while the conelets were open and erect, after allowing a couple of days for pollination to take place. Application was with a hand atomizer designed to fit directly on the one-pint measure thus eliminating the need for pouring or mixing chemicals in the field. Each cone was thoroughly wetted, but with care to avoid excessive run-off or drift to neighboring branches. As safety precautions, respirators and protective rubber clothing were worn during application. Using this method, two concentrations of the treatments were applied with each of the 10 insecticides plus a Renex-control and a water control, as listed in Table 1. For each insecticide the two concentrations used and character of the chemical is given in the Appendix.

Table 1. Seed damage in Douglas-fir cones treated with various insecticides per treatment.

Treatment	Seed damaged by --		Sound seed per cone cut
	Douglas-fir cone moth	cone midges	
	<u>pct.</u>	<u>pct.</u>	<u>no.</u>
Guthion	0.0*	4.5*	0.8
Thimet	.5*	11.0	.8
Sevin	10.0*	4.2*	.8
DDT	10.2*	9.2	.6
Rotenone	7.2*	12.2	.9
Trithion	8.0*	15.0	1.1
BHC	14.5	21.0	1.0
Malathion	18.5	15.8	.8
Dieldrin	21.0	22.8	.6
Check-Renex	27.0	22.8	.4
Sytam	29.0	24.5	.7
Check-untreated	36.5	13.8	.6

* Significantly different from check-untreated at 5 percent level of probability for Douglas-fir cone moth and from Check-Renex for cone midges.

Examinations were made after 3, 6 and 16 weeks to detect possible external injury by the treatments to the cones or foliage. In August all treated cones were picked. Five cones were selected at random for analysis and sectioned longitudinally on the knife-cone cutter. Counts were recorded on seed exposed on the cut surface as "total," "filled," and insect-damaged by species. (Winjum and Johnson, 1960)

The two sample trees differed significantly in insect attack but their interaction with treatment was non-significant, and different concentrations of insecticide were non-significant. Accordingly, these consistent result data were pooled by insecticide to show significant effects of insecticides in Table 1. Guthion, Thimet, Rotenone, Trithion, Sevin, and DDT each gave significant control of the Douglas-fir cone moth. The fir cone worm which attacks later on in the year was not significantly affected. For the Douglas-fir cone midge when compared to the Rexex-control Guthion and Sevin were significantly different. The number of filled or sound seed did not vary significantly with treatment. Examination and conelet counts at 3, 6, and 16 weeks after treatment showed that the insecticides had not burned the foliage or caused abnormal cone abortion.

In the spring of 1959 the second insecticide study was conducted with Guthion dust (3%), Guthion spray (0.5%), Sevin dust (3%), and DDT² spray (0.5%), applied at different dates. This study was carried out on the same two trees used in the bagging study on the Gilbert Forest Proving Ground. An additional 16 branches, one in each of the 16 tree crown segments were selected and tagged. The conduct of this insecticide study in parallel with the bagging study gave a stronger indication of the optimum date of spray application than if conducted separately. The insecticides were applied on the following dates: April 13, April 26, May 11, and May 25. The sprays were applied by the hand atomizer, and the dust with a hand duster. The cones were collected in late August from each treated branch and 4 cones were selected at random for laboratory examination -- except for a few cases where fewer cones were available. The cones were dissected scale by scale, and the number of insects and number of damaged seed recorded. Only cone midges were present in sufficient numbers to analyse. The results of this study are shown in Table 2.

Both Guthion dust and spray gave good control when applied at the time conelets were open and the midges were most numerous, as shown by the bagging study. The results for Sevin were not so good. The inconsistently high number of 14 midges for tree no. 2 on April 13 is based on only two cones available for analysis instead of four. One cone had no midges, whereas the other had 29 indicating that it may have been missed in dusting with Sevin. Consistently, DDT gave the least control. These results substantiate those of 1958. The brief period of oviposition by midges places control application on an exacting schedule. From recent investigations

^{3/} Sevin spray was called for in the work plan, but was unavailable commercially until after the deadline date for spraying.

Table 2. Number of Douglas-fir cone midges per Douglas-fir cone treated with four insecticides at four dates in 1959.

Tree number	Insecticide	April 13	April 27	May 11	May 25	Average of dates
1	Guthion dust	16	0*	24	47	22
	Guthion spray	29	4*	20	25	19
	Sevin dust	11	1*	21	23	14
	DDT spray	40	12	74	23	37
	Untreated check	--	--	--	--	36
2	Guthion dust	2*	20	6	4	8
	Guthion spray	2*	10	14	9	9
	Sevin dust	14	2*	13	16	12
	DDT spray	22	16	17	12	17
	Untreated check	--	--	--	--	16

* Control treatment effective.

with new insecticides for codling moth control, Madsen and Hoyt (1958) found that Guthion and Sevin gave the best control of the insecticides tested.

In the spring of 1959 a test of DDT spray, 0.25% and Guthion dust, 3%, applied by helicopter was conducted on the Clemons Tree Farm. The insecticides were applied at the time the cones were open for pollination. In late August cones were collected from 12 segments (3 vertical zones in 4 horizontal quadrants) of the crowns of 8 treated trees. These cones were sliced and examined for insect damage. All cones were heavily infested with cone midges, thus providing a good basis for testing the efficacy of control. Analysis of data, however, showed no significant difference in midge infestation due to the helicopter application of insecticide. Neither did the midge infestation differ by height in the tree or aspect of quadrant. The application of insecticides by helicopter presents problems that need to be solved before this method is dependable.

PRECAUTION ON USE OF INSECTICIDES

It is essential to point out some of the dangers of using insecticides, especially the newer highly toxic ones. Many of these insecticides have never been used in forestry, though they have made their mark in agriculture. It is not the purpose of this paper to review the serious problems that have resulted from the indiscriminate use of pesticides, but to emphasize the importance of making every effort to prevent such happenings in the use of forest pesticides.

The first precaution is that of protecting those using the insecticide from injury or death. Many insecticides are as toxic to man as they are to insects. Use extreme caution and follow directions on the container label. Those using insecticides should be thoroughly familiar with the following precautions taken from Agriculture Handbook No. 120 (1958). The Oregon Agricultural Chemical Applicators Manual (1956) and the Agricultural Chemicals Handbook (undated) should be consulted for legal aspects, and many helpful suggestions on all aspects of use of chemicals.

Insecticides are poisonous. Handle them with care. Follow the directions and heed all precautions on the container label. When handling or mixing concentrated insecticides, avoid spilling them on your skin and keep them out of your eyes, nose, and mouth. If any is spilled on the skin or clothing, wash it off and change your clothing immediately. Wear a respirator and goggles when working with concentrated sprays or dusts. Many of the new insecticides can be absorbed directly through the skin in hazardous quantities. In applying them, try to keep them off your skin and away from your eyes, nose, and mouth. Work on the windward side of the crop or animal being treated. When you have finished the job, wash all exposed surfaces of the body with soap and water. Change your clothing if any insecticide spilled on it. Parathion,

methy1 parathion, EPN, TEPP, Guthion, Phosdrin, and demeton are extremely poisonous. They should be applied only by a person thoroughly familiar with their hazards who will assume full responsibility for safe use and comply with all the precautions on the labels. The relative toxicity of the chemicals used in this study are given in the Appendix. If you accidentally swallow an insecticide, induce vomiting by taking 1 tablespoonful of salt in a glass of warm water. Repeat if necessary. Call a doctor. If you cannot obtain locally immediate information concerning symptoms and treatment of cases of actual or suspected poisoning by insecticides, call the U. S. Public Health Service at Savannah, Ga., or Wenatchee, Washington.

Another important consideration is that of protecting wildlife and domestic animals present on the sprayed area that use the same land on which we grow trees. Rudd and Genelly (1956) cover the problem of pesticides and their relation to wildlife. To protect fish and wildlife, be careful not to contaminate streams, lakes, or ponds with insecticides. Do not clean spraying equipment or dump excess spray material near such water. Avoid getting this material onto pasture grass or feed.

There are other problems that may have even more lasting effects and defeat the purpose for which control was intended. Indiscriminate use of insecticides may upset the balance of the arthropod (insects, mites, spiders) population so that problems far more serious than the one existing in the first place are created. Ripper (1956) summarizes the information on the effects of pesticides on the balance of arthropod populations. Some of the well documented effects are the increase of mite and aphid infestations caused by reduction in their natural enemies or in some instances a direct and unexplained increase in egg laying following spraying. The spruce mite epidemic in the Northern Rocky Mountain Douglas-fir forest following aerial application of DDT for the control of the spruce budworm is a timely example in forestry (Johnson 1958). In some instances the reduction in competition for food brought on by killing a major plant pest may cause the rise to epidemic proportions of other pests which previously had been insignificant. One of the biggest problems confronting economic entomologists is that of insects developing resistance to insecticides. Although our applications of insecticides in forestry are not frequent enough in most instances to worry about development of resistance, spraying in seed orchards may reach the stage where it approximates those conditions in agriculture where resistance has developed. Through following above precautions, insecticides can be of tremendous aid to the forester.

SUMMARY

The six species of insects found to cause significant damage to the seed of Douglas-fir on Weyerhaeuser Company Tree Farms in the period 1957-59 are distinguished as mature larvae in a field key. These include: three moths--the Douglas-fir cone moth, the fir cone worm, and the cone phalonid; one chalcid wasp--the Douglas-fir seed chalcid, and two midges--the Douglas-fir cone midge and the Douglas-fir scale midge. Specially constructed cages were used to determine the period of emergence of these insects. The period of attack was delimited by sequential bagging and unbagging of conelets using insect-proof plastic screen bags. The period of attack was correlated with phenological development of the Douglas-fir cones to provide guide dates for successful insecticide application. Each species of insect exhibited a different period of attack. The Douglas-fir cone moth and Douglas-fir cone midge both attacked in greatest numbers during the period when the conelets were erect and open for pollination. The midge attacks were restricted to this period exclusively, whereas the moth continued attack until after the conelets had closed and begun to turn down. The Douglas-fir scale midge and the Douglas-fir seed chalcid attacked after the cones had closed--the chalcid when the cones were pendent and about three-fourths full length. The cone phalonid and the fir cone worm attacked over a less restricted period.

A test of DDT, applied by truck-mounted sprayer to 25-60 foot Douglas-fir trees on a cone-production area was successful in reducing damage by the Douglas-fir cone moth. A method of testing insecticides on individual cone-bearing branches was quite successful for selection of promising treatments. Of ten insecticides tested, Guthion and Thimet gave best control of the Douglas-fir cone moth; Guthion and Sevin for the Douglas-fir cone midge. Later tests showed these insecticides had to be applied during the period when the conelets were open to be successful in controlling the cone midge. A test of DDT and Guthion applied by helicopter did not give satisfactory results. Included is a section on precautions in the use of modern insecticides because they are relatively new in forestry.

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Table I. Bagging treatments and number of cone midges attacking cones.

Branch number	Treatment designation	Bagging description*				Number of cone midges per cone	
		April 7	April 27	May 17	Jun. 7	Tree 1**	Tree 2***
1	(1)	-	-	-	-	14	8
2	a	+	-	-	-	25	0
3	b	-	+	-	-	0	31
4	c	-	-	+	-	4	6
5	d	-	-	-	+	31	4
6	ab	+	+	-	-	0	0
7	ac	+	-	+	-	128	0
8	ad	+	-	-	+	36	0
9	bc	-	+	+	-	0	53
10	bd	-	+	-	+	0	19
11	cd	-	-	+	+	7	1
12	abc	+	+	+	-	0	0
13	abd	+	+	-	+	0	0
14	acd	+	-	+	+	40	0
15	bcd	-	+	+	+	1	5
16	abcd	+	+	+	+	0	0

* + indicates cones protected on this date by bagging
 " " unprotected " " "

** cones open April 27, closed May 11

*** cones open April 8, closed April 27

POSITIONS OF TREATMENTS IN TREE

Quadrant	N	E	S	W	Crown Ht.	N	E	S	W	Crown Ht.
	c	b	abcd	ad	top	ac	(1)	bd	abcd	top
	bcd	d	ac	ab	Upper	b	abc	acd	d	Upper
	a	abc	bd	cd	lower	cd	ad	ab	bc	lower
	abd	acd	(1)	bc	bottom	abd	bcd	c	a	bottom

Table II Chemicals tested in the study for protection of Douglas-fir cones from insect damage.

Chemical	Composition	Concentration
		<u>pct.</u>
<u>Organic phosphates</u>		
guthion	0,0-Dimethyl S-(4-oxo-1,2,3-benzotriazinyl-3-methyl) phosphorodithioate.	.1 .2
malathion	0,0-Dimethyl S-(1,2-dicarboethoxyethyl), dithiophosphate.	.1 .2
sytam	Octamethyl pyrophosphoramide	.1 .2
thimet	0,0-Diethyl, S-Ethylthiomethyl phosphorodithioate	.1 .2
trithion	0,0-Diethyl-S-(p-chlorophenyl thio)-methyl phosphorodithioate	.1 .2
<u>Chlorinated hydrocarbons</u>		
BHC	1,2,3,4,5,6 hexachlorocyclohexane	.2 .4
DDT	2,2-bis-(p-chlorophenyl)-1,1,1-trichloroethane	.2 .4
<u>Cyclodiene</u>		
dieldrin	1,2,3,4,10-10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, exo-5,8-dimethanonaphthalene	.2 .4
<u>Carbamate</u>		
sevin	N-methyl-1-naphthyl carbamate	.2 .4
<u>Rotenoids</u>		
rotenone	Natural extractive of derris root; probably several compounds	2.5 5.0
<u>Surfactant: spreader, emulsifier</u>		
Renex-20	Mixture of esters formed from reaction of ethylene oxide with unsaturated fatty acids and heterocyclic resin acids	.1

Table III

Insecticide	LD - 50* mg/kg	Toxicity to wildlife
Thimet	3.7	Extremely high
Sytam	10.0	Extremely high
Guthion	15.0	Extremely high
Trithion	28.0	Extremely high
Dieldrin	87.0	High
Rotenone	132.0	Low
BHC	200.0	Low
DDT	250.0	Low
Sevin	540.0	Very low
Malathion	1500.0	Very low
Renex-20	Surfactant; non-active chemical	

* LD-50 represents the lethal dosage causing 50 percent mortality in a test population. Mg/kg is the milligrams (of chemical) per kilogram of body weight; this relates dosage to a standard weight rather than to varying body weights of individual test animals.